JUNE 1989

AIR FORCE SCIENCE & TECHNOLOGY AND THE AIR FORCE LABORATORIES

A Report to the CSAF by
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AIR FORCE SCIENCE & TECHNOLOGY AND THE AIR FORCE LABORATORIES

In February of 1989, the Chief of Staff requested that the Chief Scientist review the Air Force laboratory system (see p. 28). The review was to address the management and technical direction of laboratories, the program formulation process, the science and technology infrastructure and operation, the relationships with the other services, DARPA, SDI, and the DOE national laboratories.

This report responds to the tasking. The views are based on visits and discussions throughout the Air Force (including all laboratories and research centers), and discussions with other services, members of the academic community, other national laboratories, and several industrial research & development organizations. They are listed in the reference section.

OUTLINE

EXECUTIVE SUMMARY

The Air Force laboratories are much better than their external reputation would suggest. They have been major contributors to the technology that the Air Force has today. They have originated new concepts and new technologies, participated in technology development, transitions to industry, and in real time assistance to the forces on technology issues.

The role of the laboratories is to provide the leadership and focus for research and development for the Air Force, linking together all of the elements that contribute to the science and technology base, from universities to industry. This is a very challenging role, as it requires participation and recognition in both these research communities.

The Air Force science and technology program is generally good. It has good science in the principal research areas needed for future Air Force technology. It addresses a broad spectrum of appropriate technology issues. The program is reasonably well coordinated at the working level among the Air Force Laboratories, and the inter-service coordination is done better than the services get credit for. The issue of duplication in the science and technology program is widely overstated.

There are some real concerns that need to be addressed to improve the science and technology program and to strengthen the laboratories. And there are opportunities for positive change in the context of the widespread concern about the erosion of the defense technology base, and the response to the Defense Management Review.

The Science and Technology Program

The science and technology program is currently organized for presentation to the leadership of the Air Force in a manner that makes it difficult to understand from the perspective of broad technology direction and emphasis. And then, rather than providing a broad direction and emphasis review, the program is actually reviewed and approved in detail in the Pentagon. Neither the science and technology program nor the people in it are well served by this situation.

The program as currently presented is essentially a compilation of the research activities of the laboratories. Good science comes from the bottom up, but overall consolidation, focus, and definition require top down technical management. The organization of the program into a smaller number of broad technology areas related to functional needs would be a great help in both the process of formulating the program and the high level technical direction and emphasis review. This should be the subject of a careful review, but the concept is illustrated

by the following technology areas -- aircraft, missiles and satellites, weapons, C4I, human resources, and supporting research. The conduct of the program and the contracting authority should then be delegated to the lowest possible level along these lines.

Laboratories

The overall mission of the laboratories has three principal elements: (1) long term high payoff research; (2) technologies needed for product development and maintenance; and (3) in-house technical expertise for the Air Force. In addition, each laboratory needs to have a unique and concise mission--a principal reason for its existence--that is clearly understood by the laboratory and its constituency.

There is an opportunity with the Defense Management Review to strengthen the management of the laboratory system and the overall long range planning and development of the science and technology program. One option is to centralize the management of the laboratories and technology planning and requirements functions, and to combine all of this with the Studies and Analysis organization at the Air Staff level. This could provide a real improvement in both the development and the coordination of the science and technology program within the Air Force, with the other services, and with OSD.

The small size and fractionation of the laboratories limit their flexibility, their ability to achieve external recognition, and opportunities for diversity and growth of their research staff. The grouping of laboratories into research centers can help to overcome this problem. But the laboratories should remain the heart of the Air Force science and technology program. The research centers should be chartered around the major functional areas discussed under the science and technology program above (i.e., aircraft, missiles and satellites, weapons, etc.). This will generally fit well with their present programs and makeup. The centers should be assigned the responsibility for planning, program development, and program management of the science and technology program in their technology area.

The issue of contractor management (FFRDCs and GOCOs are examples) is worthy of a careful look at the advantages and disadvantages for the Air Force laboratories. There are two principal characteristics of contractor management that are different. First, the civilian personnel are not in civil service--an advantage in pay and personnel management practice, but a disadvantage for in-house expertise. Second, there is some decoupling from the sponsoring organization--an advantage for independent perspective, but a disadvantage in the participation

and understanding of Air Force needs. Creativity and independence of approach are important, not independence from the Air Force.

On balance, changing the laboratories to contractor management would not solve the advanced technology problems for the Air Force. But improving Air Force management practices based on the experience of contractor managed laboratories will help. However, if the civil service system cannot improved, then contractor management may be the only way to preserve the capability of the laboratories in the long term.

We are nearing a crisis in the technical staffing of the laboratories. Almost half of the PhDs are over 50 years old and will be retiring within the next decade, as shown in Figure 1 on page 19. Adequate replacements are not being hired. The civil service system and its salary structure are probably the principal causes, as shown by the comparison of R&D salaries in Figure 2 on page 20. The current structure is a prescription for mediocrity in government service.

Changes in the civil service system, starting with adoption of the China Lake experiment, are urgently needed. There are other initiatives which can help, like the Air Force Palace Knight program to hire top undergraduates and send them to school for advanced degrees. Other changes could include improvements in laboratory capabilities, such as a substantial upgrade of supercomputing capability which would attract good people and also make the Air Force competitive in this area.

There are other issues which affect the quality of life in the laboratories and contribute to the frustration of the staff. These include deteriorating facilities for offices and research space, the increase in the fraction of research contracted outside the laboratories, and the often mindless bureaucracy of the procurement system.

Recommendations

There are six specific recommendations (p.24). They are: (1) to restructure the science and technology program into a few broad technology areas related to functional needs; (2) to charter the research centers with program development and management responsibility for those areas; (3) to establish a management process where the senior leadership addresses only broad program directions, emphasis, and major demonstrations; (4) to consider a centralized management structure for the laboratory system and technology planning, possibly combined with SA at the Air Staff level; (5) to establish a recruiting campaign for technical PhDs; and (6) to de-bureaucratize the civilian personnel practices in the laboratories to the extent allowed by law.

INTRODUCTION

There has been increasing concern voiced over the state of the defense science and technology base in recent years, and numerous studies have been conducted addressing the issue (ref. 1-3). The U.S. depends on technical superiority as a key component of our national defense posture, so the issue is quite relevant.

National security in the broadest context extends beyond defense alone and encompasses the overall political and economic strength of the country. Defense technology is in the broadest sense inseparable from the overall technological strength of the country, and the changes in the world in the last two decades clearly show that the U.S. no longer stands alone as the world's technology leader. The world political situation is also changing in a manner that is likely to significantly reduce the national resources devoted to defense for some time to come. In this context maintaining a "technological edge" becomes even more important.

Technology for defense systems today is not the unique purview of defense laboratories. It is developed from a broad national and international base of research and development activities in universities, defense laboratories, other national laboratories and research organizations, and industry.

The Role of Defense Laboratories

The role of the defense laboratories is generally described in terms of assuring the defense technology base, transitioning technology for military systems, and playing the role of the technically knowledgeable buyer for the DOD. These are important, but there is another fundamental and critical role for the defense laboratories. This role is to provide the leadership and focus for research and development activities that are important for defense technology, linking together all of the elements that make up the science and technology base.

The University community generally conducts long range basic research that advances the state of knowledge. Industry generally is focused on research and development that has a recognizable application and opportunity for a return on the investment. The defense laboratories have the very challenging task of bridging the gap and influencing and focusing the content of the research at both ends of this spectrum. This requires them to be recognized participants in both basic and applied research activities.

In the first decades after World War II, defense research and development was at the forefront across a wide spectrum of technology that subsequently "spun-off" into commercial applications. Today, a significant fraction of technology development is being conducted in the commercial arena, and internationally as well. This also creates another task for the defense laboratories, the "spin-on" of commercially developed technology. The successful utilization of dual-use technologies will be critical to maintaining defense capabilities in the coming decades.

In sum, the role of the defense laboratories is more important and more challenging than is generally recognized. It is important to the long term technical capability of our military systems that the laboratory system be kept healthy, and properly directed to be working on the right programs.

Previous Studies of Defense Technology Base and Laboratories

There is an extensive history of studies conducted on this subject. The 1987 Defense Science Board Study (ref. 3) cited sixteen such studies conducted since 1966. By including an important 1961 study for Dr. Harold Brown (ref. 4), the DSB study, an Air Force study by Dr. Harold Sorenson (ref. 5), and the most recent OTA study (ref. 1), the total is 20 studies since 1960. This is equivalent to one study every other year, and there actually are more that could be cited.

This history has some important lessons in that there are common issues which are cited by many of the studies, and there are common themes in the recommendations. It is instructive to look at the 1961 report to Dr. Brown. It concluded that there were serious morale and capability problems in the defense laboratories due to the following: (1) The salaries of top scientists and engineers were not competitive with industry. (2) The laboratories were buried "within a wearisome administrative structure." (3) There was a lack of effective executive management. (4) Many laboratories were handicapped by sub-standard facilities. This list could have been compiled in 1989.

The problem areas and recommendations for change cited in all the subsequent studies vary with the focus of each group, but they are more similar than they are different. The principal areas are: (1) attracting and retaining high quality technical staff; (2) low salary and personnel system bureaucracy; (3) lack of good management; (4) the need for external technical review; (5) the need for more research flexibility and continuity; (6) deteriorating facilities; and (7) problems with technology transfer.

The 1987 DSB study recommended some specific changes such as centralized management of 6.1 research and converting the management of the defense laboratories to GOCO (government owned, contractor operated) facilities. A centralized knowledge of what is going on in basic research is clearly worthwhile, but basic research is inherently an area which should be "managed" as little as possible. The idea is to generate ideas. The proper role for management in 6.1 research is to support good people and institutions and to define the appropriate technology areas and broad directions for defense science. The issue of GOCO is dealt with later in this report.

The 1983 White House Sciences Council Study chaired by David Packard (ref. 6) encompassed all federal laboratories. They reached many of the conclusions noted in the summary above, but also recognized a very important fact in the federal laboratory system. In almost every case, the best laboratories were those that had clearly defined important missions that had been stable over a long period of time.

AIR FORCE SCIENCE & TECHNOLOGY

The State of the Program

The Air Force science and technology program is generally good. It has good science in the principal research areas needed for future Air Force technology. It addresses a broad spectrum of appropriate technology issues. The program is reasonably well coordinated at the working level among the Air Force Laboratories and between the services. The inter-service coordination is better than the services get credit for.

The issue of duplication in the science and technology program is widely overstated. In research and exploratory development there are many technology areas that are described by similar general words, but embody many differences in technical details and in desired capabilities. For example, IR sensors are an important, complex, and challenging technology area with applications for weapons, aircraft, and space systems across all the services. It is essential to have many research activities going on, and even competitive approaches. As technology matures and moves toward system development coordination becomes more important. The keys are to assure that the strategic approach to the technology area is agreed at the management levels, and the details are coordinated at the working levels.

Program Formulation and Organization

The development of technology needs from operational capability needs has been well done. A version of mission area analysis is employed, with using commands addressing their future needs. This approach has provided good insights into operational user needs and perspectives, and it has involved the operational users in thinking about future technology requirements. The hierarchy of operational capability needs is not entirely clear, however, so there are difficulties in establishing research priorities.

The program today contains generally good science and technology programs which have been directed toward the right areas to provide capabilities for useful systems in the future. But the program is currently organized for presentation in a manner that makes it difficult to understand from the perspective of a broad technology direction and emphasis. And then, rather than providing a broad direction and emphasis review, the program is actually reviewed and approved in detail at the Pentagon. Neither the science and technology program nor the people in it are well served by this situation.

Good science comes from the bottom up, but overall consolidation, focus, and definition require top down technical management. The science and technology program can be defined and structured more simply and clearly so that it will be better understood by the leadership of the Air Force, OSD, and the Congress, as well as the AF operational commands and the laboratories themselves.

The Air Force science and technology program currently presented is essentially a compilation of the research activities of the laboratories. The program is presented in twelve technology areas. They are Air Vehicles, Materials, Avionics, Aeropropulsion, C4I, Human Systems Technology, Civil and Environmental Engineering, Conventional Armament, Space & Missiles, Geophysics, Advanced Weapons, and Research Sciences. This is a mix of functional areas, research disciplines, and supporting technologies. It is not hierarchical, and the multiple interdependence and connectivity of the areas make an overall management perspective very difficult.

Organization of the program into a smaller number of broad technology areas generally related to functional needs would be a great help in both the process of formulating the program and the high level technical direction and emphasis review. In sum, better understanding and management of the resource investment in technology.

The actual structure and subdivision needs to be the subject of a separate study focusing on capturing all the elements into this kind of approach. This structure should not be dictated by the historical divisions among the laboratories, as the idea is to provide new definition and focus to the program. It also cannot be hostage to the current definition of program elements. Rather, the program elements should also be restructured to reflect a well thought out overall approach to the program development process and overall manageability at the technology policy level.

For illustration, the technology areas could be aircraft, missiles and satellites, weapons, C4I, human resources, and supporting research. Each area would then be subdivided into major subareas such as the following: aircraft--aerodynamics, structures, propulsion, avionics, and stealth; missiles and satellites--propellants, rocket engines, exoatmospheric missile design, space power, space propulsion, and space structures; weapons--cruise missiles, rockets, weapon avionics, warheads, explosives, and directed energy; C4I--C2 technology, computers, networks, software research, and technology for intelligence (surveillance, etc.); human resources--man-machine interface, human protection technology, medical research, and training research; and supporting research--the 6.1 program.

The idea here is that the senior leadership of the Air Force would establish the overall emphasis between the technology areas, and between the major subareas. The execution of the program would then be left to the laboratory system management. To be specific, senior management would provide research guidance which included areas of emphasis, top level issues, major demonstration projects, etc., and the conduct of the program and contracting authority would be delegated to the lowest level possible. Only technology area and sub-area plans and accomplishments would be reviewed at the senior level.

THE AIR FORCE LABORATORIES

The State of the Air Force Laboratories

The Air Force laboratories are much better than their reputation would suggest. They have been major contributors to the technology that the Air Force has today. They have originated new concepts and new technologies, participated in technology development, transition to industry, and in real-time assistance to the forces on technology issues.

The laboratories often do not get credit for what they do. When their technology successfully transitions to industry, it often reappears in proposals for systems and industry gets the credit. Or, DARPA takes on and expands an area originated in a laboratory and subsequently gets more visibility and recognition. Only about half of the research activities being conducted by the Air Force laboratories is actually sponsored by the Air Force. (The principal external sponsor is SDIO, then the other services.) The laboratories put in considerable effort to integrate the external programs with Air Force programs to produce more benefit for the Air Force and the other sponsors. This is a significant leveraging of Air Force science and technology resources.

The laboratories are often criticized by external groups for not matching up to the standards of an academic research laboratory. In many cases, these review groups do not appreciate the role the laboratories must play in bridging the gap between universities and industry. The Air Force laboratories are not chartered to create research laboratories that are the same as MIT. They are chartered to work with MIT to focus research and apply it to defense needs. But it is also true that to do this they need to be as good as MIT in certain areas.

As a further insult, many of the external groups have never taken the time to visit or understand the laboratories. There are areas of research excellence in each of the laboratories that are of the highest quality. These exist in some areas of material science, computational fluid dynamics, plasma physics, nonlinear optics, hydrodynamics, geophysics, solid state sciences, and others. In addition, the labs have world class experimental facilities for aerodynamics and fluid flow, explosive phenomenology, propulsion systems, and a variety of electromagnetic phenomenology.

After all this, however, it has to be noted that there are very real concerns and problems that need to be addressed in the laboratory system. These include the quality of the staff,

management and organization, and facilities, each of which will be addressed in more detail below. There is also a concern that in contrast to the world class experimental facilities, the capability for large scale computational modeling and analysis is far behind the rest of the research community in industry, universities, the DOE laboratories, and NASA.

Laboratory Role and Mission

The role and mission of the laboratories needs to be clearly stated and understood by both the Air Force as a whole and by the laboratories.

The role of the Air Force laboratories is to provide the technical leadership and focus for science and technology that is important for future Air Force capabilities. To accomplish this they must link together all the elements that make up the defense science and technology base, from universities to industry. And providing the linkage between basic academic research and applied industrial research and development for Air Force technology is a challenging role indeed. It requires participation and recognition in both these research communities.

The overall mission of the laboratories has three principal elements. The first is leadership in long-term, high-payoff research, including research in specialized long-term, enabling technologies. The second is leadership in developing technologies needed for product development or maintenance, including assuring that appropriate other elements of the technology base are involved. And third is in-house technical expertise for the Air Force.

In addition to the general role & mission, every laboratory needs to have a principal reason for its existence that is clearly understood by the laboratory and its constituency. If it doesn't, then it probably should not exist. This principal mission (reason for existence) should be unique for each Air Force laboratory and can be programmatic, functional, or disciplinary. But the principal mission should not restrict the diversity of the research activities in the laboratory.

All of the most successful research laboratories have clearly identified principal missions, and many also have a broad range of other research activities. Some examples are: Naval Research Laboratory--principal basic research lab for the Navy; DOE weapon laboratories--nuclear weapons; AT&T Bell Laboratory--basic and applied research supporting communications technology; and the Air Force Materials Laboratory--materials science and technology for the Air Force.

The Air Force relies on its laboratory system for a great deal of the technology program planning. This is appropriate because that is where the technical knowledge resides. But a serious drawback is that there is essentially no system analysis capability in the laboratories to help them develop a better understanding of the relevance or leverage of technology on military capabilities. Strengthening the laboratories in this area would help in the translation of military capability needs into technology needs, and improve the long range planning of the science and technology program.

The laboratories would also benefit from more in-house engineering capability. The connection of laboratory technology with real world applications is an important part of their role, and yet almost all the engineering is transferred to the product division or the contractors. The DOE labs and Bell Labs all have some engineering capabilities and responsibilities.

Management and Organization

The Air Force laboratories have been organized into several centralized and decentralized organizational structures since WWII, and there has been ongoing discussion about the merits of these different kinds of organization. There is no right way, and, in fact, organization is not the first consideration. It is more important to focus on the role and mission--what the laboratories are supposed to do--and then make the characteristics of the organization facilitate that action.

The decentralized management structure that currently exists in Systems Command facilitates the linkage with the product divisions, which are the laboratories' principal customers, and the development programs and technology needs. This structure can also make it easier to obtain additional resources for important programs.

A centralized management structure facilitates the development of a coherent Air Force-wide science and technology program. It provides a visibility and advocacy at a high level in the organization, and can help with the interservice coordination and defense of the program.

Both a coherent Air Force-wide S&T program and good linkage with the customers are important for the laboratories. But neither will work perfectly no matter what the organization, and that is the case today.

Centralized Management

In the context of budget pressure, the need for a more coherent and more coordinated program, increased scrutiny from OSD and the Congress, and the changes resulting from the Defense Management Review, a centralized management system will probably be the most effective. This is an opportunity to address some options for changes that would strengthen the laboratories and the program planning and development process.

The lack of an overall capability to do long term technology planning based on studies and analyses translating military requirements into technology requirements has been cited as a real problem in the development of the long range science and technology program. Some such capability needs to be resident in each laboratory to help with their own research program development. But this function is even more important at the headquarters level in the long range planning of science and technology to support the Air Force of the future.

One option is to centralize the management of the laboratory system with the long range technology planning and requirements functions as a science and technology command reporting at the four-star level within a system or materiel command.

Another option would be to combine the centralized laboratory system and planning and requirements functions with an expanded Studies and Analysis organization at the Air Staff level. This could provide a central focus for long range technology planning and analysis for the Air Force as a whole. It would also be an advantage in coordinating the science and technology program within the laboratory system, with the Secretariat, with the other services, and with OSD consistent with Goldwater-Nichols and the Defense Management Review.

Research Centers

The small size and fractionation of the laboratories limit their flexibility to pursue research opportunities, and to their capability for establishing an external identity. Individually they do not have the resources to bring to bear on some activities, and there are limited opportunities for diversity and growth for the scientific staff within the organization. By comparison, the Naval Research Laboratory, the DOE weapon laboratories, and the AT&T Bell Laboratories are substantially larger.

The grouping of laboratories into research centers can help to overcome this problem. Theodore von Karman (ref. 7) suggested in the late 1940s that Air Force research be focused in functional areas of importance to Air Force technology. There are some clear advantages to this approach today in addressing the size and flexibility problems as well as research program development. Centers focused around the major functional areas discussed in the section on the science and technology program (i.e., aircraft, missiles & satellites, weapons, C4I, human resources) would fit reasonably well with the laboratory system as it exists today.

The centers should be assigned the responsibility to develop and coordinate the science and technology programs in their broad technology area, as well as the leadership and support of the laboratories in their organization. The programmatic responsibilities of the centers need to be clearly defined in mutually supporting fashion, with assigned lead roles in all the technology areas. Individual laboratories often are the focus of technical discipline area research for the Air Force, and maintaining this capability would be an important task for the centers.

The laboratories should continue to be the heart of the Air Force science and technology program. They are the centers of expertise, they recruit and maintain the technical staff, and they actually conduct the program. Much of the focus of the management process should be directed to strengthening the laboratories.

The center management needs to recognize that small size and fractionation are issues for the laboratories. This means that the centers should strive for consolidation, not more fractionation. The creation of large project organizations and subdividing laboratories is going in exactly the wrong direction. There is a clear need for program management and external points of contact on program issues. And there is a need for a small staff to do systems thinking and planning. But the execution of all the programs should be done in the laboratories.

In this same vein, the consolidation of organizations to form a laboratory could also be beneficial. This is especially true in those cases where this could leave a center management free to concentrate on the other issues discussed in this section. Geographic diversity is also a problem, but it is prudent to plan to do the best possible to minimize the impact. (It is very difficult to make changes that involve people dislocations and strong political constituencies.) Certainly there should not be two centers represented on the same physical location.

And finally, contracting should not be done from the center headquarters. The emphasis should be on strengthening the laboratories and incorporating as much of the execution of the program as possible within the laboratories. The center leadership should concentrate on science and technology program planning and management, and on personnel policy, facilities, procurement policy, and other issues to improve the ability of the laboratories to conduct the programs.

Contractor Management

Contractor management has been suggested by several studies over the years as a means of resolving some of the staffing problems in the federal laboratories. (Two well recognized forms of contractor management are the FFRDC and the GOCO.) Contractor management was explicitly suggested by the 1987 DSB study (ref. 3), and was analyzed again in the 1989 OTA study (ref. 1). Thus it is important to consider the advantages and disadvantages specifically for the Air Force laboratories. Understanding the role and missions of the Air Force laboratories are key in evaluating the potential benefits of contractor management. The external studies which have been the most critical of defense laboratories often have different roles and missions in mind.

Almost any rational management system, like any rational organizational structure, can successfully work. The questions are whether a particular approach helps more than some other, and if it does, is the change worth it?

There are two general characteristics of contractor management that are different than Air Force management. The first is that civilian personnel would not be in civil service. This is a clear benefit for pay scale and personnel management policy, but the people would no longer be in-house Air Force employees. The second characteristic is that the laboratory would be decoupled to some extent from the sponsoring organization. This would allow somewhat more independent views, and somewhat more research freedom. It would also result in being somewhat less well in tune with the Air Force acquisition and operational organizations.

This latter characteristic is clearly subject to management policy and contractual arrangements; it can be mitigated by good management, but will always be present. Good management and good people should be able to achieve the positive aspects of independence in either a government or a contractor situation. Creativity and independence of approach are important, not independence from the Air Force.

Is contractor management the reason the DOE weapon laboratories

enjoy such a good technical reputation? Yes, in part. They exhibit the characteristics described above--higher salaries than the federal laboratories, less oppressive personnel policies, more independence from their sponsor (DOE), and some degree of academic flavor. Their relationship to the nuclear weapons industry is not a good point for comparison of contractor management issues since this is a captive industry. But there are some other things that affect their quality that are not dependent on contractor management.

The DOE weapon laboratories are large multidisciplinary institutions with programs ranging from basic research to production engineering. They have the flexibility and the resources (within limits) to address important issues as they arise. They have diverse career paths for their people. They have stability and quality in technical leadership. They have to abide by all the same contracting, travel, procurement, rules, etc., as the federal laboratories but they have their own in-house organizations to manage all this with much less frustration to their employees. They have problems maintaining facilities also, but they are not nearly as severe as the defense laboratories because they do not compete with the military construction budget.

In the final analysis, the only major desired role for the laboratories that is difficult with contractor management is that of the knowledgeable (in Air Force) in-house laboratory technical expertise. This would have to be accomplished by careful contractual arrangements. It could be less effective, or lead to the re-creation of some sort of in-house technical capability, perhaps even laboratories. But much of the perceived advantages of the DOE GOCO laboratories is really derived from better management practices.

In balance, conversion to contractor management is probably not the optimum answer for the Air Force. Instead, efforts should be made to incorporate some of the lessons available from the successful contractor managed organizations into the Air Force system. But there is one important caveat. As the supply of good technically trained people continues to decrease, the competition for these people will become even more intense. Unless something can be done about the civil service system, like at a minimum adopting the China Lake system, the supply of good, new technical talent will disappear. Then contractor management may be the only way to maintain adequately capable laboratories.

People

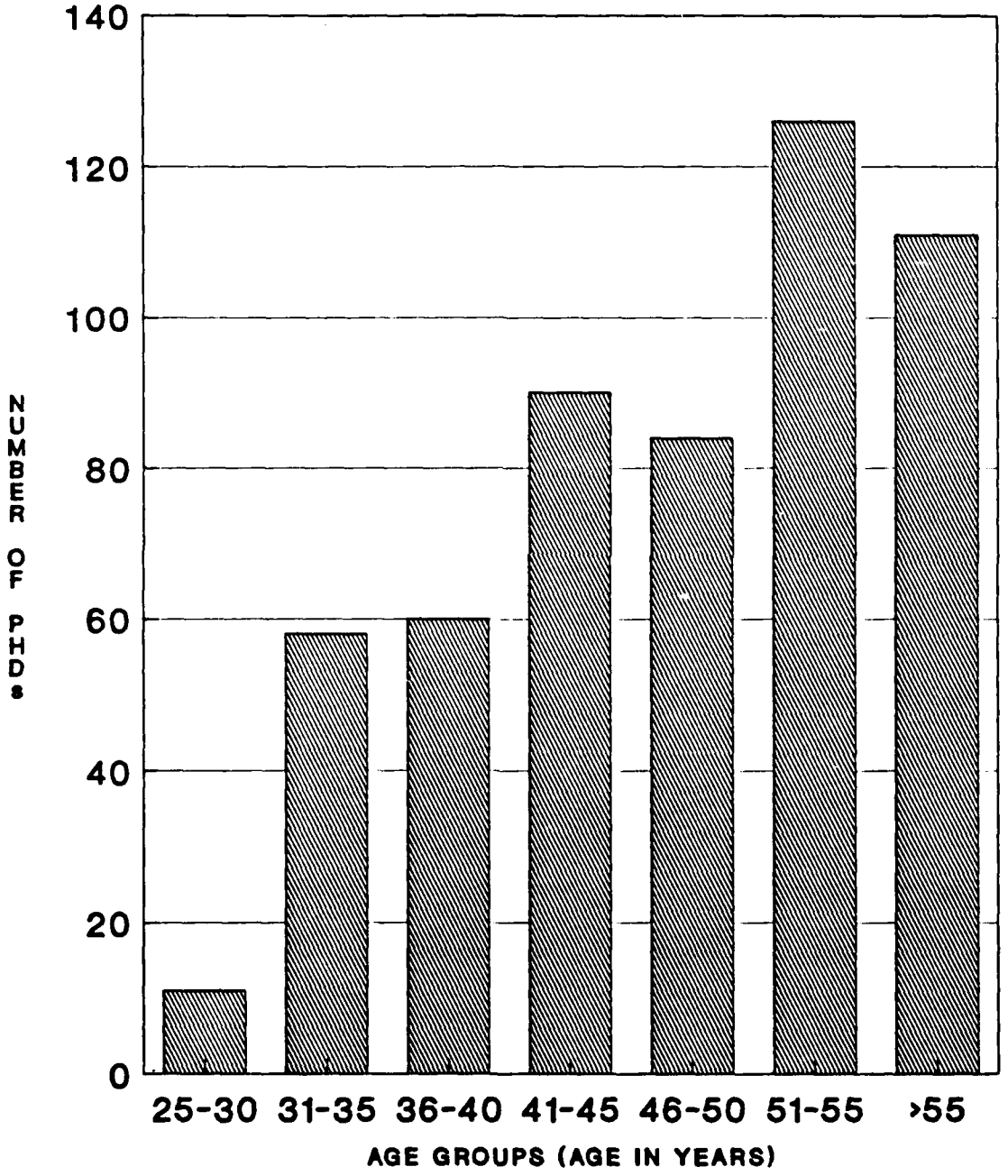
Good people are key to all organizations. The Air Force laboratories have some very good people, both in the civilian staff and uniformed military. High quality people are the reason for the areas of excellence which exist in every laboratory. Nevertheless, attracting and retaining high quality technical staff is a key issue for the laboratories.

The demographics of the PhDs in the laboratories show a very serious problem of an aging population that is not being regenerated with young, new talent. The data presented in Figure 1 on page 19 illustrates what should be regarded as a crisis in staffing the laboratories. Nearly half of the PhDs are over 50 years old, and will probably retire in the next ten years. And the very low numbers of younger people show that adequate replacements are not being hired. This data forecasts a dramatic change in the character of the laboratories--a significant reduction in scientific capability--that will make the laboratories unable to fulfill their role and mission. Recruiting and hiring high quality scientific talent is not a simple matter. Placing job ads may produce applicants, but they will not be the high quality people the laboratories need. Recruiting these people takes years of committed effort of building many personal contacts within the good graduate schools. And as the competition for technical talent gets more intense, the Air Force laboratory system will need to find ways to remain competitive. Programs like the new Palace Knight initiative for hiring people at the Bachelors degree level and providing the advanced education will help.

There have always been a variety of nonmonetary rewards for technical people working in the Air Force laboratories. But, as the facilities deteriorate, advanced research tools like supercomputers are not acquired, and with the increasing bureaucracy in personnel, procurement, etc. the quality of life is eroding. In this context, the increasing salary difference with the rest of the world is clearly taking its toll.

The disparity in salary for scientific and technical people between the federal laboratories and other institutions is shown graphically in Figure 2 on page 20. This chart is extracted from data collected by the American Institute of Physics. The column labelled "FFRDC" includes institutions like the DOE weapon laboratories and Lincoln Laboratory.

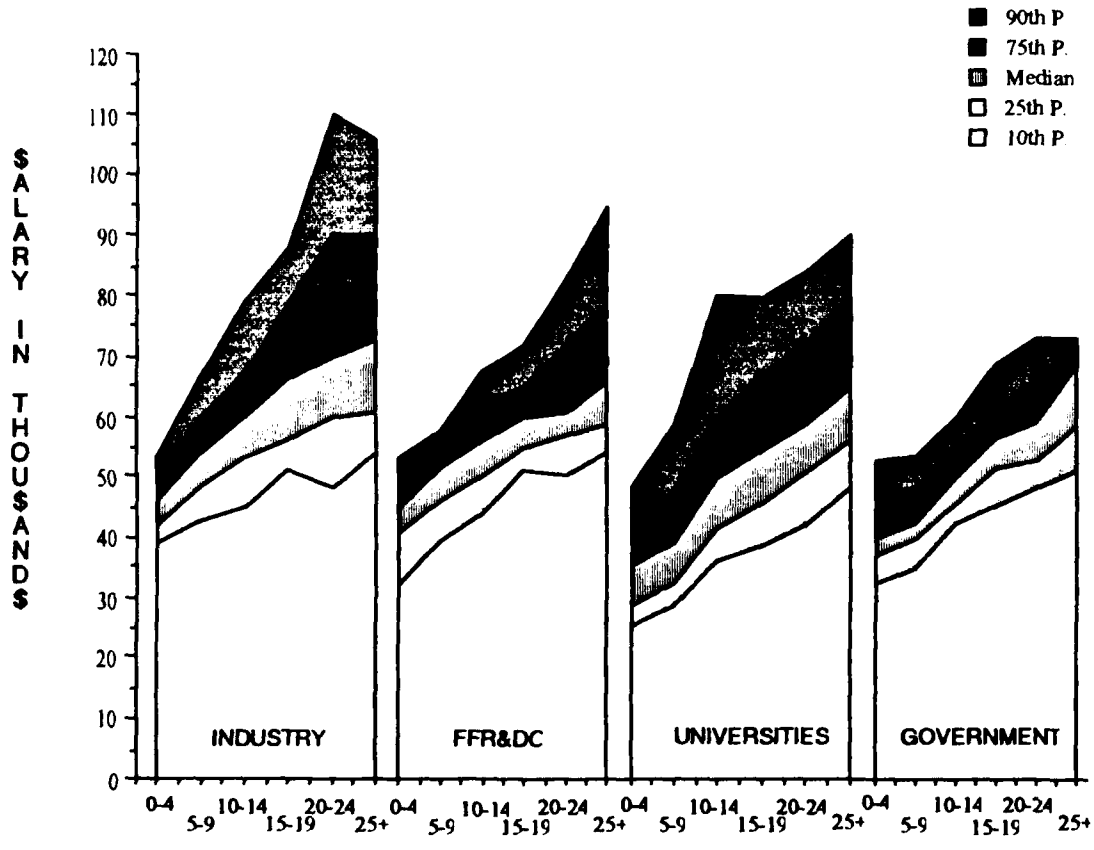
AGE DISTRIBUTION OF CIVILIAN PHDs IN AIR FORCE LABORATORIES



TOTAL PHDs = 540

Figure 1

TECHNICAL SALARY STRUCTURE IN INDUSTRY, FFR&DC, UNIVERSITIES, AND GOVERNMENT BY YEARS FROM PHD, 1987



SOURCE: AIP MEMBER SOCIETY SURVEY, 1987

Figure 2

There are two principal observations about the data. The first is that the median starting salaries are about 25% lower for the federal laboratories than for industry or FFRDCs. This makes the competition for the top new graduates very difficult. The second is that the wide range of salary for the senior people is more important than the median. This shows that industry, FFRDCs, and universities are all paying more to attract and retain the top people who supply the intellectual leadership. It should be observed that some of the spread in industry is due to higher salaries for management people. Nevertheless, the federal structure is a clear prescription for mediocrity in government over the long term.

This issue is a significant challenge to the civil service system. Adoption of some major reforms like the China Lake experiment are essential. This would remove a great deal of the bureaucracy in process, classification, grade controls, etc., and allow more management flexibility in hiring and promotion. Another provision would be to allow some number of exceptions to the salary cap to bring in some nationally recognized senior people. And finally, the creation of a significant number of new ST positions to support the parallel ladder concept and recognize senior technical people in ways outside the direct use of salary. (There should be 4 or 5 more at every laboratory.)

Another technique of bringing in new people, at least temporarily, is through the use of staff exchanges with other laboratories. The federally funded laboratories such as Lincoln Laboratory and the DOE weapon laboratories would be especially good for this sort of an exchange program. This would also serve another end, which is the increased use of the resources available at these institutions to address some of the challenging technology problems for the future. This has been an area of some paranoia on the part of the Air Force laboratories (and other defense laboratories). But the Air Force laboratory staffs are underrating their own capabilities. In the areas where they are good, they are as good as the DOE labs, and would find that the exchange would be mutually beneficial.

The technically trained uniformed military have made very important contributions to the laboratories over their history. And service in the laboratory system has contributed to a more technically knowledgeable officer corps. Unfortunately, the numbers of technically trained officers is declining and there is a widespread perception that a laboratory assignment is a negative factor in their career. And there are statistics that bear this out. In 1979 there were 33 active duty general officers who had served at least one tour in an Air Force laboratory, while at the end of April 1989 there are only 9.

The Air Force has long held the reputation of being the most technically capable service. These trends suggest that this is changing. And it will also change the character of the laboratories, making them much more like the mostly civilian organizations in the Army and Navy laboratory systems. This is a policy issue that deserves attention.

Other Issues

In-House Research

A recent study of in-house activity in the laboratories (ref. 8) noted that the Air Force devotes less of its 6.1 resources to in-house activity than either of the other services. The Air Force spends 25% in-house, the Army 60%, and the Navy 80%. Since the laboratories are being called upon to interface and collaborate with universities in areas of importance to the Air Force, and the Air Force laboratories have no other source of basic research funding, a better balance should be struck.

Facilities

One of the important resources of the Air Force laboratories are their experimental facilities. These facilities are a national asset and an important part of the capability of the laboratories to contribute to the development of future technology. And they are important for attracting good people to the laboratories.

Opposite to these experimental facilities are the facilities for people, such as office space. These are generally in poor condition, with incidents of leaking roofs and numerous other troubles. These facilities have been an issue for decades, and the laboratories are going to need to use existing funding to address some of these problems.

The capability of the laboratories to do theoretical calculations and large scale mathematical modeling and analysis are not nearly as good as their experimental capabilities. The Air Force research community is barely into supercomputing compared with universities, industry, the DOE laboratories, and NASA. A commitment to acquiring and using supercomputers as a part of the research program will attract good people, improve the use of the experimental facilities, and lead to better collaboration with other institutions.

Procurement

Procurement probably causes as much frustration in the laboratories as any other issue. This process is the subject of considerable legislation, but the real problem in many cases is classic mindless bureaucracy. The imposition of regulations designed for billion dollar acquisitions to million dollar (or less) research enterprises benefits nobody. At minimum, each laboratory or center needs its own procurement staff to help them get through the system.

RECOMMENDATIONS

1. Restructure the science and technology program for better perspective and appropriate management by the leadership of the Air Force. Technology areas defined generally along major functional areas could accomplish this; for example, aircraft, missiles and satellites, weapons, C4I, human systems, and supporting research. A small senior group should define these areas along with possible program element redefinition and the program management roles to be given the research centers.

2. Assign each of the major technology areas defined above to a research center, and give them the responsibility for the program development and management of the science and technology program in their technology areas.

3. Establish a management process by the leadership of the Air Force that considers only broad directions, emphasis, accomplishments, and major technology demonstrations. Program conduct and research contracting authority should be delegated to the lowest possible level.

4. Consider a central management organization for the laboratory system combined with the technology planning and requirements functions. Also consider combining this system with Studies and Analysis at the Air Staff level and providing a charter that includes long range technology planning, analysis, and program development, and coordination with the Secretariat, the other services, and OSD agencies.

5. Establish a long term recruiting campaign for top quality scientific PhD people for the laboratories. It should include all the Air Force laboratories in a unified effort. And it should include programs in place such as fellowships, post-doctoral appointments, and the Palace Knight initiative, but go well beyond this in establishing links and recruiting efforts in major universities.

6. Take steps today to change Air Force civilian personnel management practices within the laboratory system to the limits allowed by law. This should include relaxing grade controls, allowing classification by managers versus personnel officers, management to total laboratory budget, drastically reducing the time for various approvals and managing by exception, and adding several ST positions at every laboratory.

REFERENCES

1. U.S. Congress, Office of Technology Assessment, "Holding the Edge: Maintaining the Defense Technology Base," OTA-ISC-420, April 1989

2. Report of the Ad Hoc Industry Advisory Committee, Subcommittee on Defense Industry and Technology, Senate Armed Services Committee, Feb. 5, 1988

3. "Technology Base Management," Report of the Defense Science Board 1987 Summer Study, Office of the Under Secretary of Defense for Acquisition, December 1987

4. Carl Berger, "The Strengthening of Air Force In-House Laboratories 1961-1962," USAF Historical Division Liaison Office, December 1962

5. Science and Technology in the Air Force, A focus on Air Force Laboratories, A Briefing to General Welch, July 1988.

6. Report of the Federal Laboratory Review Panel of the White House Science Council, Office of Science and Technology Policy, May 1983

7. Theodore von Karman, "Toward New Horizons -- Science, the Key to Air Supremacy," A Report to General H. H. Arnold, December 1945

8. In-House Activity at AFSC Laboratories, Allen Schell, Chief Scientist AFSC, Draft, June 1989

VISITS AND DISCUSSIONS

AIR FORCE LABORATORIES
- Wright Research and Development Center - Col Paul,
  - Dr. Ritchie & Center leadership
  - Avionics Laboratory - Dr. Ryles & staff
  - Electronics Laboratory - Mr. Remski & staff
  - Flight Dynamics Laboratory - Dr. Olsen & staff
  - Materials Laboratory - Mr. Russo, Dr. Burte & staff
  - Propulsion Laboratory - Dr. Curran & staff
  - Cockpit Integration Directorate - Lt Col Smith
  - Manufacturing Technology Directorate - Mr. Schulz
  - Technology Exploitation Directorate - Mr. Haas
- Space Technology Center - Col Johnson, Dr. Janni & staff
  - Astronautics Laboratory - Col Nunn, Dr. Weiss
  - Geophysics Laboratory - Col Kidd, Dr. Carlson
  - Weapons Laboratory - Col Otten, Lt Col Oliver, Mr. Godfrey
- Rome Air Development Center - Col Shulstad, Dr. Diamond, et al
- Armament Technology Laboratory - Col Marchiando, Dr. Lambert
- Armstrong Aeromed. Lab & Human Resources Lab - Dr. Welch, et al

AIR FORCE SYSTEMS COMMAND
- Headquarters - Gens Randolph, Ferguson & Dr. Schell
- Aircraft Systems Division - Lt Gen Loh
- Human Systems Division - Maj Gen Doppelt
- Munitions Systems Division - Gens Staten & McElroy
- Space Systems Division - Gens Cromer & Rankine
- AFOSR - Col Driscoll, Dr. Dimmock
- AFIT - Brig Gen Boyd, Dr. Przemieniecki

HQ USAF & SAF

General Welch	Mr. Welch
General Hatch	Dr. Cohen
Lt Gen Smith	Dr. Kohn
Lt Gen Yates	Mr. Ksycewski
Maj Gen Alexander	Mr. Moseman
Maj Gen Lamberson	Mr. Neufield
Brig Gen Douglass	Dr. Paiewonsky
Brig Gen Loy	Mr. Schittulli
Col Bianco	
Col Heitz	
Col Woody	

HQ AFLC - General Hansen, Mr. Panzarella & staff
AFOTEC - Maj Gen Powell, Dr. Williams & staff
ESD - Brig Gen Roberson, Mr. Sommers & staff
Edwards Flight Test Center - Maj Gen Schoeppner & staff
HQ TAC - Gen Russ, Brig Gen Ralston, & Mr. Endersen
HQ SAC - Maj Gen Peat, Mr. O'Meara & staff
HQ MAC - Gen Cassidy, LtGen Burshnick & staff

DEPARTMENT OF DEFENSE
Office of Research & Advanced Technology - Dr. Millburn
Assistant Secretary for Atomic Energy - Dr. Barker
SDIO - LtGen Monahan, Dr. Judd
DARPA - Dr. Fields
DEPARTMENT OF THE ARMY - Dr. Singley
Army Laboratory Command - Brig Gen O'Neill
DEPARTMENT OF THE NAVY
Chief of Naval Research - RADM Wilson, Dr. Saalfeld
Naval Research Laboratory - Dr. Coffey & staff
National Academy of Sciences - Dr. Press, Director
National Science Foundation - Dr. Moore, Deputy Director
Lawrence Livermore National Laboratory - Mr. Nuckolls (Director), Dr. Holzrichter
Los Alamos National Lab - Dr. Hecker (Director), Dr. Jackson, Dr. Miller, Dr. Birely, Dr. Brown, Dr. Hopkins
Sandia National Laboratory - Dr. Narath (President), Mr. Clem
USAF Scientific Advisory Board - Dr. Lucky, Dr. Bridges, Dr. Stear, Dr. Sorenson, Dr. Stubberud, Dr. Naka
Lincoln Laboratory - Mr. Morrow, Director
Congressional Office of Technology Assessment - Dr. Sharfman, Dr. Shaw, Dr. Epstein
UNIVERSITIES
Univ. of Calif. - Dr. Frazer, Dr. York
Harvard Univ. - Dr. Branscomb, Kennedy School of Government
Univ. of Illinois - Dr. Smarr
MIT - Dr. Deutsch, Provost
Princeton Univ. - Prof. Happer (also Chairman JASON)
INDUSTRY
AT&T Bell Labs - Dr. Buchsbaum (Vice President), Dr. Lucky
General Atomics - Mr. Blue, President
Hughes - Dr. Mendel, Vice President for Research
RAND - Dr. Tompson, Dr. Donahue
Rockwell Int'l - Dr. Yarymovych, Dr. Longo (Lab Director)
Westinghouse - Dr. Longuemare, Vice President
INDIVIDUALS
Mr. Gerry Johnston, President, McDonnell Douglas
Dr. Robert Kupperman, Technical Advisor, CSIS
Dr. Al Lovelace, Vice President, General Dynamics
General Tom Marsh
Mr. David Packard, President, Hewlett-Packard
General Bernard Schriever
Dr. Richard Wagner, Vice President, Kaman Science

DEPARTMENT OF THE AIR FORCE
OFFICE OF THE CHIEF OF STAFF
UNITED STATES AIR FORCE
WASHINGTON, D.C. 20330

23 FEB 1989

Dear Dr. Selden

Our laboratories played a key role in giving the Air Force the superiority we have now in our operational forces. To maintain this superiority, we must continually challenge ourselves to even better management of our laboratory efforts in support of user needs and to exploit technology opportunities.

As Chief Scientist you have devoted considerable attention to understanding our laboratory structure and the role the labs play in developing technology and transitioning technology into weapon systems and into the field.

General Randolph and I would like your further views on management and technical direction of the Air Force laboratories. How well is our laboratory system working? Is our program formulation methodology sound? Are our Science and Technology infra-structure and operations postured properly? Are our relationships with the other Services, academe, industry and national laboratories oriented to get us the best technology base? Have we addressed productivity and duplication of effort appropriately?

Receiving your comments by early June 1989 would be helpful.

Every best wish

Larry D. Welch

LARRY D. WELCH, General, USAF
Chief of Staff

Atch
Ltr fr Gen Randolph
to Gen Welch dtd 8 Feb 89

cc: AFSC/CC (Gen Randolph)

Dr. Robert W. Selden
Chief Scientist
Headquarters United States Air Force
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Washington, D.C. 20330

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE DC 20334-5000

8 FEB 1989

General Larry D. Welch
Chief of Staff
United States Air Force
Washington DC 20330-2000

Dear Chief

Our laboratories have done superb work to get us the technological superiority we have now in our combat forces and support structure. Today, the labs are postured to continue to give our future forces the technological edge. I'm convinced we have the right approach to manage our technology developments and ensure a continued support of user needs and exploitation of technology opportunities. Others outside the Air Force, though well intentioned, may not share this view.

I believe Dr Bob Selden is uniquely positioned to help us convince others our lab system is not broken. I've been impressed with what Bob has done for our program in the short time he's been on board. He understands our laboratory structure and the role labs play in not only developing technology, but transitioning technology into weapon systems and into the field.

I propose we jointly ask Bob for his views on management and technical direction of the Air Force laboratories. I have attached a letter for your consideration.

Sincerely

[redacted], General, USAF
Commander

1 Atch
Proposed Ltr to Dr Selden